American

POTATO JOURNAL

Volume 34 *November 1957* *Number 11*

CONTENTS

Official Publication of

THE POTATO ASSOCIATION OF AMERICA

NEW BRUNSWICK, NEW JERSEY, U. S. A

American Potato Journal

PUBLISHED BY
THE POTATO ASSOCIATION OF AMERICA
NEW BRUNSWICK, N. J.

Price $4.00 per year in North America; $5.00 in other countries.

Entered as second class matter at New Brunswick, N. J., March 14, 1942 under Act of March 3, 1879. Accepted for mailing at special rate of postage provided for in section 412, Act of February 28, 1925, authorized on March 14, 1928.

SUSTAINING MEMBERS

THE RELATION OF PHYSICAL PROPERTIES AND CHEMICAL COMPOSITION TO MEALINESS IN THE POTATO. II. CHEMICAL COMPOSITION[1]

A. M. UNRAU[2] AND R. E. NYLUND[3]

INTRODUCTION AND LITERATURE REVIEW

In a previous paper (30), some experimentally determined relationships between mealiness and certain physical properties of the potato were described. This paper is a report of studies on the chemical composition of potatoes and its relationship to mealiness.

Many investigations (3, 6, 13) have dealt with the chemical composition of potato tubers. Likewise, many experiments have been conducted to determine the relationships between various chemical components and quality characteristics of potatoes. Only papers of the latter type related to this report are reviewed.

Several characteristics which may be attributed to physiological changes occurring in the raw tuber have a definite effect on the cooking quality of potato tubers. For instance, high sugar content imparts a sweet taste to boiled potatoes which is generally considered to be undesirable. Appleman (2) showed that increases in sugar content during storage of tubers at approximately 32° F. was at the expense of starch. Sweetman (29) states that tubers will become sweet when stored at any temperature below 40° F. and that sugar accumulation is detrimental to flavor, mealiness and other culinary qualities. The sugar content of tubers which have been stored at low temperatures can be reduced by conditioning at 68-72° F. for 10-14 days which in effect removes accumulated sugars by increasing respiration rates and/or partially reconverting sugar to starch. It is of considerable value to be able to predict general quality of tubers and from results of relatively recent experiments, Heinze *et al* (15) concluded that dry matter, alcohol insoluble solids, starch content and specific gravity all gave reliable quality predictions.

Several studies on the relationships between nitrogen compounds and quality of potatoes have been reported. As early as 1897, Coudon and Bussard (10) reported that the ratios of nitrogen and protein nitrogen to starch were highest for non-mealy potatoes and lowest for mealy tubers. Rathsack (27) reported that high nitrogen content appeared to have a deleterious effect on palatability. Harcourt (14) and East (12), however, found no relation of nitrogen or protein nitrogen to quality of potatoes. Of considerable interest are also the physical and chemical nature of the proteins and other nitrogenous components of the potato. The early fractionation of potato proteins by Osborne and Campbell (26) and a series of more recent investigations, notably by Neuberger and Sanger (24), Chick and Slack (7), Slack (28), Levitt and Todd (21) and Levitt (18, 19, 20) describe potato proteins in some detail.

[1]Accepted for publication April 17, 1957.
Paper No. 3748 of the Scientific Journal Series of the Minnesota Agr. Exp. Sta.
[2]Formerly Research Assistant, Department of Horticulture; at present, Research Assistant, Department of Biochemistry, Univ. Farm, St. Paul, Minn.
[3]Associate Professor, Department of Horticulture.

The relation of starch content to mealiness in the potato has been recognized for some time. The positive correlation of starch content with mealiness has been shown by a number of investigators (5,8,9). However, simple starch determinations yield no information concerning the two components of starch and their relative concentrations. By a spectrophotometric assay for amylose, McCready and Hassid (22) determined the amylose/amylopectin ratios for various starches and found that potato starch contained about 25 per cent of the straight chained polymer amylose, the rest being the branched chain polymer, amylopectin. Because of the different physical properties of these two starch components (16), variations in the relative concentrations of each could well alter the gelling properties of starch granules and thus affect mealiness of boiled potatoes. Some evidence that the gelling properties of different tuber groups vary has been presented by the authors in a previous paper (30).

MATERIALS AND METHODS

Conditions and cultural practices under which the potatoes that were used in these experiments were grown are described elsewhere in this journal (30). Wherever possible, the same tubers which had been used for organoleptic tests were used for subsequent chemical analysis. Where separate tubers were used, these were drawn from tuber lots that had received the same post-storage conditioning treatments as those used for organoleptic tests.

1. *Dry Matter*:

Dry matter was determined by treating raw, ground tubers with a constant volume of 0.5 per cent sodium bisulphite to prevent excessive air oxidation and then drying the samples of tissue first at 67° C. and then to constant weight at 85-90° C.

2. *Ash Determinations*:

Portions of raw, ground tissue (no bisulphite added) were dried to constant weight and this material was used for ash determinations. A constant volume of magnesium acetate was added to the samples of pulverized dry tissue and these mixtures were then ignited in an electric muffle furnace at 750-800° C.

3. *Nitrogen Content*:

Nitrogen determinations were carried out on dried tissue (bisulphite added during drying) as follows. The tissue samples were partially digested with concentrated sulphuric acid until a translucent, brown liquid was obtained. This solution was then adjusted to a desired volume with distilled water and the nitrogen in small volumes of the diluted solutions determined using the method of Lanni, Dillon and Beard (17). The solubility of the nitrogenous components was determined by extracting weighed quantities of finely ground, raw tissue with distilled water, dilute salt solution, or 85 per cent ethanol (aqueous) and then determining the nitrogen content of these solutions.

4. *Analyses for Soluble Sugars*:

Soluble sugars were determined by the Lane-Eynon method (25) and by paper chromatographical analysis. Simple sugars were extracted

with hot 85 per cent ethanol. Aqueous solutions of the sugars were used in the Lane-Eynon method. Alcoholic solutions were used in the quantitative chromatographical analysis as follows: microliter quantities of solution were transferred to paper chromatograms which were developed for 36-40 hours using n-butanol ethanol: water as the irrigant. The sugar bands were located by spraying narrow marginal strips with Tollens reagent. The sugars were eluded from the paper with water and then determined quantitatively by the phenol-sulphuric acid spectrophotometric method of Smith *et al.* (11).

5. *Determination of Non-Starch Polysaccharide*:

Pulverized lyophilized tissue was soaked in water, filtered through asbestos Gooch filters, and the soluble proteins removed by precipitation with trichloroacetic acid. The solutions did not give a color with iodine — KI reagent. The sugar content was determined directly on the aqueous extract. The amount of polysaccharide was calculated by subtracting from the obtained values the total soluble sugar values previously determined by chromatographic analysis.

6. *Determination of Starch Content*:

Starch content was determined by acid hydrolysis and by the polarimetric method of Balch (4). In the acid hydrolysis, samples of dried, ground tissue were hydrolysed in sealed tubes using 0.5 N sulphuric acid. After neutralization of the hydrolysates with barium carbonate, the material was filtered while hot, the precipitate washed several times with hot water, the final volume of filtrate evaporated under reduced pressure, and the residue dissolved in 95 per cent ethanol. The amount of glucose was determined chromatographically.

7. *Fractionation of Pure Starch*:

In order to conduct some of the experiments described in succeeding paragraphs, it was necessary to obtain pure starch from the different specific gravity tuber lots of each of the three varieties. Raw tubers were thoroughly macerated in a Waring blender using 0.5 per cent sodium bisulphite solution as the initial extractant. The starch granules were separated from the lighter non-starch material by a series of centrifugations and re-suspensions until a white, granular product was obtained. The starch was dried by extraction with absolute ethanol, acetone, and ether in that order and then ground in a Wiley mill to pass a 60 mesh screen, and finally passed through a 120 mesh bolting silk screen. The purity of the final product was determined by hydrolysis of small quantities of the starches in the usual manner followed by chromatographic and polarimetric determinations of glucose. The starch samples were further analyzed with respect to purity by the method of Balch (4) and comparing the experimental figures with the reported specific rotation of starch (+193°).

8. *Fractionation of Amylose*:

Starch, from one of the prepared samples, was fractionated into amylose and amylopectin using the method of Montgomery, Hellman and Senti (23). The amylose obtained by this method was further purified by fractional precipitation with alcohol. An amylose fraction was obtained which gave $E^{1\%}_{1\ cm.}$ value similar to that obtained for a reference sample of amylose prepared by another method. The amylose sample obtained

was used as a standard in the determination of amylose-amylopectin ratios of the various starch samples.

9. *Determination of Amylose — Amylopectin*:

The various starch samples were analyzed for amylose content by the method of McCready and Hassid (22). Instead of using 100 milligram quantities suggested in this method, 500 milligram quantities were used to ensure better sampling. A number of determinations were made for each starch sample.

10. *Periodate Oxidation Studies*:

Small amounts of amylose and amylopectin were subjected to periodate oxidation following essentially, the method of Abdel-Akher and Smith (1). Similarly, periodate oxidations were carried out on various potato starches. Using the combined data from these experiments, the previously determined amylose-amylopectin ratios, and the amount of formic acid produced in the oxidation of amylose, the incidence of branching of the amylopectins of the various starch samples was estimated.

RESULTS AND DISCUSSION

The dry matter, ash and protein contents of tubers from the 1954 crop are given in table 1. Although there is a fairly close correlation between mealiness and dry matter content, this association does not hold for varietal comparisons. Whereas differences between the dry matter contents of high specific gravity Red Pontiac, Cobbler and Waseca are small, the mealiness score of the Red Pontiac sample is significantly lower than those of the other two varieties. Similarly, in the comparison of lower specific gravity tuber lots, only small differences in dry matter exist but Waseca was scored significantly higher in mealiness than the other two varieties. Within varieties, mealiness is directly proportional to dry matter content (and specific gravity) in Cobbler and Waseca, but not in Red Pontiac.

The ash content of raw tubers of Red Pontiac appears to be somewhat higher than in comparable lots of the other two varieties. This difference is not evident in the boiled tubers. As indicated by the correlation coefficients, there is little, if any, association between mealiness and ash content.

Total crude protein in both raw and boiled tubers appears to be inversely related to specific gravity. However, little association between protein content and mealiness is apparent. Solubility studies show that more than ⅔ of the total extractable nitrogenous material was dialyzable. This indicates that most of the nitrogen is present as small polypeptides, free amino acids or nitrogen bases. The data in table 1 indicate that mealiness is negatively correlated with the content of nitrogenous material solution in 85 per cent ethanol. This association would be of real significance if, for instance, the simple nitrogenous compounds in some manner acted as "mortar agents" between gelatinized starch granules or as anti-swelling agents by forming a protective layer around the partially gelatinized starch granules.

Sugar, polysaccharide and starch contents are presented in table 2. The rather high concentrations of total sugars in Red Pontiac tubers

TABLE 1.—*Dry matter, ash, and protein content of potatoes differing in variety and/or specific gravity and the mealiness scores of each tuber lot.*

Variety and Spec Gravity	Mealiness Score	Dry Matter	Ash in Dried Tissue of: Raw Tubers	Ash in Dried Tissue of: Boiled Tubers	Crude Protein in: Raw Tubers	Crude Protein in: Boiled Tubers	"Protein" Soluble in 85 per cent Ethanol
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Red Pontiac							
1.065	3.0	17.9	....	....	....	....	......
1.080	5.2	23.8	4.29	3.47	8.39	7.20	1.58
1.100	4.9	26.2	3.70	2.90	7.50	6.51	1.68
Cobbler							
1.080	5.4	24.0	3.64	3.31	9.45	7.73	1.64
1.100	7.9	27.3	3.24	2.88	7.37	7.02	1.15
Waseca							
1.080	6.2	24.9	3.60	3.35	8.97	8.18	1.15
1.100	8.0	27.7	3.64	2.87	7.27	7.12	1.17
"*r*"—With mealiness		.88*	—.61	—.57	—.66	—.01	—.87*

*Correlation coefficient significant at the 1 per cent level.

and in low specific gravity Cobbler and Waseca may, to some extent, account for the lower degree of mealiness of these tuber lots. The high concentrations of sugars, and soluble polysaccharides may act in the same manner as previously suggested for the small molecular weight nitrogenous compounds.

Although mealiness is apparently negatively correlated with polysaccharide content, low specific gravity Waseca tubers contained approximately the same amount of polysaccharide as did Red Pontiac tubers, yet were scored significantly higher for mealiness. This points out that mealiness cannot be related to a single factor but is most probably affected in varying degree by a combination of factors.

The data for starch content are also shown in table 2. Since the values obtained by different methods were in reasonably close agreement, only those obtained by acid hydrolysis are shown. In general, starch content was directly proportional to specific gravity. However, it should be noted that tubers of identical specific gravity but differing in variety do not necessarily have the same starch content. Low specific gravity Red Pontiac had a lower starch content than comparable samples of Cobbler and Waseca. Although a positive relationship between mealiness and starch content is evident, the low mealiness score of high specific gravity Red Pontiac cannot be explained on the basis of starch content alone.

The results from a number of tests suggested that the prepared starch samples (which were later used for amylose determinations) were reasonably pure. In a series of acid hydrolyses of the different starch samples, the specific optical rotations of the solutions after 5 hours hydrolysis ranged from 51.1° to 53.9°. The glucose recovered chromatographically ranged from 95.7 to 97.9 per cent of the theoretically expected amount of glucose. These values are within a reasonably narrow error

TABLE 2.—*Glucose, fructose, sucrose, total sugar, polysaccharide and starch contents of potatoes differing in variety and/or specific gravity.*

Variety and Spec. Gravity	Mealiness Score	Percentages (On a dry wt. basis) of:					
		Glucose	Fructose	Sucrose	Total Sugar	Polysacc. as Glucose	Starch
Red Pontiac							
1.065	3.0	.....	.....	.....	.....	5.91	63.0
1.080	5.2	1.93	1.42	2.08	5.43	4.06	66.5
1.100	4.9	1.31	1.06	1.61	3.98	2.27	78.6
Cobbler							
1.080	5.4	0.86	0.43	1.19	2.48	2.55	73.6
1.100	7.9	0.38	0.21	0.55	1.14	1.41	79.6
Waseca							
1.080	6.2	0.41	0.58	1.22	2.21	2.39	70.6
1.100	8.0	0.59	0.25	0.57	1.41	1.39	77.3
"*r*" with mealiness					—.82*	—.88**	.94**

range. Further tests for purity included the measurement of optical rotation of starch solutions according to the method of Balch (4) and then relating the specific rotations to samples of starch of known purity. The results obtained are shown in table 3. The data show that the samples were of a high degree of purity and it appears that the rotation values reported for pure starch should be revised upward.

Using the method of McCready and Hassid (22), the amylose that was fractionated from one of the starch samples was compared to reference samples of amylose and was found to compare favorably. Using the prepared amylose sample as a reference standard in the preparation of a standard curve, the amylose contents of the various starch samples were determined by the method mentioned above. The results are presented in table 4. In general, starch from the low specific gravity tubers contained less amylose. Cobbler and Waseca tubers contained more amylose than did Red Pontiac tubers of the same specific gravity. Mealiness and amylose content are positively correlated. It should be noted that the low specific gravity Waseca tubers scored higher in mealiness than the low specific gravity Cobbler, and also contained more amylose.

The relative amounts of the two components of starch, amylose and amylopectin, may be important in influencing mealiness of potatoes because of differences in the chemical and physical properties of these components. Amylose exists as long alpha — 1,4 — linked polyglucosan chains. This chain is spacially arranged in the form of a spiral or helix, and upon treatment of a solution of amylose with iodine — KI reagent, the typical blue to purple iodine—amylose complex results.

Because of the straight, unbranched chain arrangement of amylose, parallel alignment of the individual chains and strong hydrogen bonding occurs and leads to a rigid crystalline complex. This tendency toward chain alignment causes amylose to retrograde rapidly after it has been dissolved in hot water and allowed to cool.

TABLE 3.—*The purity of the starch samples as determined by the optical rotation of starch solutions, concentration 1 per cent.*

Variety	Specific Gravity	Observed L	$[L]^{22}_{D}$	Purity Per cent*
Red Pontiac	1.065	1.86	204	105.8
	1.080	1.90	209	108.1
	1.100	1.90	209	108.1
Cobbler	1.080	1.87	205	106.5
	1.100	1.87	205	106.5
Waseca	1.080	1.89	207	107.6
	1.100	1.85	203	105.2
Corn Starch		1.83	201	104.1

*Values based on the reported specific rotation of starch of 163°.

TABLE 4.—*Amylose contents of starch from the different tuber lots.*

Variety	Specific Gravity	Mealiness Score	Per cent Amylose: In Pure Starch	In Lyophilized Tissue	On Fresh Wt. Basis
Red Pontiac	1.065	3.0	26.9	16.9	3.13
	1.080	5.2	31.6	21.7	5.17
	1.100	4.9	33.6	26.3	6.66
Cobbler	1.080	5.4	32.8	24.5	5.88
	1.100	7.9	36.0	29.7	8.10
Waseca	1.080	6.2	36.7	27.2	6.79
	1.100	8.0	35.2	28.7	7.81
"r" with mealiness			0.86*	0.90**	0.93**

Amylopectin is also an alpha -1, 4- linked polyglucosan but an additional linkage exists in that periodically a branch point occurs in which a 1,4,6 linkage is involved, the C_6 of a glucose molecule of one chain linked to a C_1 glucose of the other chain. This type of branching gives amylopectin an arborescent structure more easily hydrated and consequently more water soluble. Amylopectin shows very little, if any, tendency toward retrogradation.

Because of these differences in physical properties, high concentrations of amylose in potato starch may confer greater mealiness while high amylopectin content may cause pastiness in boiled and mashed potato tissue. The relationship apparent between amylose content and mealiness, as shown in table 4, agrees with this supposition.

The solution tendency of amylopectin could conceivably vary somewhat depending on the degree of branching or the length of the repeating unit. Thus, short chain lengths of the repeating unit result in a denser "tree-like" molecule, whereas longer chain lengths would give a more open structure. The chain lengths of the repeating units of amylopectin in

the different starch samples as determined by periodate oxidation studies are presented in table 5. Short chain lengths indicate a greater branching frequency. The less mealy samples apparently contain amylopectin with a greater degree of branching than do the more mealy samples. Since, as indicated previously, the hydration of the more highly branched chains would be greater, this factor could conceivably contribute to pastiness or stickiness of boiled potato tissue. This observation warrants further study.

TABLE 5.—*The chain lengths (moles anhydro-glucose per repeating unit) of amylopectin in starch of the different tuber lots.*

Variety and Spec. Gravity	Mealiness Score	Moles Anhyd. Glucose/ Repeating Unit*
Red Pontiac		
1.065	3.0	16.6
1.080	5.2	15.5
1.100	4.9	14.8
Cobbler		
1.080	5.4	16.4
1.100	7.9	18.2
Waseca		
1.080	6.2	18.1
1.100	8.0	18.4
"r" with mealiness		.69

*Calculated on basis of amylopectin content of the starch sample.

SUMMARY AND CONCLUSIONS

1. Chemical characteristics which were found to be associated with mealiness are:
   (a) dry matter content, (b) starch content, (c) sugar and polysaccharide content, (d) content of small molecular weight nitrogen compounds, and (e) amylose content.
2. Mealiness is apparently not associated with (a) crude protein content and (b) ash content.
3. Characteristics which need further investigation to determine more precisely their relation to mealiness in potatoes are: (a) the nature of the polysaccharides that are apparently present in potatoes, (b) the physical effects of high concentrations of soluble sugars, polysaccharide and nitrogen-containing compounds on gelling of starch granules in potato tubers, and (c) the molecular structure of the two components of potato starch — amylose and amylopectin.

Acknowledgment:

The authors wish to express their thanks to Dr. W. F. Geddes for making available facilities of the Department of Agriculture Biochemistry. The many helpful suggestions of Dr. L. S. Cuendet, formerly of the Department of Biochemistry, and Dr. F. Smith, Department of Biochemistry are gratefully acknowledged.

Literature Cited

1. Abdel-Akher, M., and F. Smith. 1951. The repeating unit of glycogen. J. Amer. Chem. Soc. 73: 994-996.
2. Appleman, C. O. 1912. Changes in Irish potatoes during storage. Md. Agr. Exp. Sta. Bull. 167.
3. Atwater, W. O. and A. P. Bryant. 1906. The chemical composition of American food materials. U.S.D.A. Office of Exp. Sta. Bull. 28 (Rev. ed.).
4. Balch, R. T. 1941. Rapid determination of starch with sodium hypochlorite. Ind. Eng. Chem., Anal. Ed. 13; 346-348.
5. Bewell, E. R. 1937. The determination of the cooking quality of potatoes. Amer. Potato Jour. 14: 235-242.
6. Brautlecht, C. A., and A. S. Getchel. 1950. The chemical composition of white potatoes. Amer. Potato Jour. 28: 531-550.
7. Chick, H., and E. B. Slack. 1949. Distribution and nutritive value of the nitrogenous substances in the potato. Biochem. Jour. 45: 211-221.
8. Child, A. M., and J. J. Willaman. 1929. Culinary quality in potatoes. Amer. Potato Jour. 6: 259-268.
9. Cobb, J. S. 1935. A study of culinary quality in white potatoes. Amer. Potato Jour. 12: 335-346.
10. Coudon, H., and L. Bussard. 1897. Recherches sur la pomme de terre alimentaire. English Abstr. in Jour. Chem. Soc. 72: 514 (1897).
11. Dubois, M., K. Giles, J. K. Hamilton, P. A. Rebers and F. Smith. 1951. A colorimetric method for the determination of sugars. Nature 168: 167.
12. East, E. M. 1908. A study of the factors influencing the improvement of the potato. Ill. Agr. Exp. Sta. Bull. 372.
13. Goldthwaite, N. E. 1925. Variations in composition of Colorado potatoes. Colo. Agr. Exp. Sta. Bulls. 296 and 297.
14. Harcourt, R. 1907. Composition and cooking quality of potatoes. Farmers Inst. of Ontario 12th Report 1906; 71-79.
15. Heinze, Peter H., Mary E. Kirkpatrick and Elsie F. Dochterman. 1955. Cooking quality and compositional factors of potatoes of different varieties from several different locations. U.S.D.A. Tech. Bull. 1106.
16. Kerr, Ralph W. (Ed.) Chemistry and industry of starch. Academic Press Inc. Publ. New York, 1950.
17 Lanni, F., M. L. Dillon and J. W. Beard. 1950. Determination of small quantities of nitrogen in seralogical percipitates and other biological materials. Proc. Soc. Exp. Med. 74: 4-7.
18. Levitt, J. 1951. The isolation and preliminary fractionation of protein from dormant and growing potato tubers. Plant Physiol. 26: 59-65.
19. ————. 1952. Two methods of fractionating potato tuber proteins and some preliminary results with dormant and active tubers. Physiol Planta. 5: 470-484.
20. ————. 1954. Investigation of the cytoplasmic particulates and proteins of potato tubers. III. Protein synthesis during the breaking of the rest period. Physiol. Planta. 1: 597-601.
21. ————, and Glenn W. Todd. 1952. Metal protein complexes in the potato. Physiol. Planta. 5: 419-429.
22. McCready, R. M. and W. Z. Hassid. 1943. Spectrophotometric determination of amylose - amylopectin. Jour. Am. Chem. Soc. 65: 1154-1157.
23. Montgomery, Edna M., N. N. Hellman and F. R. Senti. Fractionation of corn starch by sedimentation. (Unpublished) Northern Regional Laboratory, Peoria, Ill.
24. Neuberger, A., and F. Sanger. 1942. The nitrogen of the potato. Biochem. J. 36: 662-671.
25. Official and Tentative Methods of Analysis. 1940 Edn. Assoc. Official Agr. Chemists.
26. Osborne, T. B., and G. F. Cammbell. 1896. The proteids of the potato. Jour Amer. Chem. Soc. 18: 575-578.
27. Rathsack, Carl. 1935. *Der Speisewert der Kartoffel.* Berlin. Verlagsgesellschaft für ackerbau m.b. th. 1935.
28. Slack, E. B. 1948. The nitrogenous constituents of the potato. Nature 161: 211.
29. Sweetman, Marion Deyoe 1936. Factors affecting the cooking quality of potatoes. Maine Agr. Exp. Sta. Bull. 382.
30. Unrau, A. M. and R. E. Nylund. 1957. The relation of physical properties and chemical composition to mealiness in the potato. I. Physical properties. Amer. Potato Jour. 34: 245-253.

A COMPARISON OF SOD CROPS FOR USE IN ROTATION WITH POTATOES[1]

T. E. Odland and J. E. Sheehan[2]

Introduction

Growing potatoes continuously year after year on the same land eventually leads to decreased yields and poorer quality potatoes. This fact is generally recognized by potato growers. The question is what crop will best maintain favorable soil conditions so that satisfactory crops will result. Another important question is how often is it necessary to introduce such a crop in rotation with potatoes. The Rhode Island potato grower generally plants rye following the potato harvest and plows this down the following spring for the next crop of potatoes. This practice helps to maintain favorable soil conditions but does not supply sufficient organic matter to compensate for losses during the growing seasons. Since the potato grower generally does not have livestock he is not interested in growing a crop for hay or pasture in rotation with potatoes — he is more interested in a crop that can be managed with the least amount of labor and the least outlay for equipment. This means in most cases a sod crop that can be clipped periodically during the growing season and left on the ground rather than cut for hay.

Many experiments in crop rotations including potatoes have been conducted both in Rhode Island and in other states. However, relatively few have been conducted where potatoes grown continuously on the same land have been compared with rotations where potatoes are grown every other year or for a number of years following an alternate crop. The latter is the kind of rotation in which the commercial potato grower is most interested. Terman (*3*) reports results from potato rotation experiments in Maine where continuous potatoes were compared with potatoes grown in rotation with green manures in alternate years. Average increases up to 50 bushels per acre were obtained where the potatoes were grown following green manure crops. Various green manure crops were used including both legumes and non-legumes. Japanese millet was the most satisfactory green manure crop to alternate with potatoes.

Smith (*2*) states that in earlier years a common rotation in upstate New York consisted of 2 or 3 years of some hay crop followed by potatoes. This practice has now been largely abandoned and potatoes are grown in shorter rotations or in continuous culture on the better land of the farm. On Long Island most potatoes are grown on the same area each year with a cover crop of rye seeded just after harvest.

Redtop has been one of the best crops to precede potatoes in experiments at this station. In one of these experiments (*1*) potatoes grown continuously yielded 478 bushels per acre whereas following redtop sod the average yield was 580 bushels of U. S. No. 1 potatoes per acre.

---

[1]Accepted for publication May 8, 1957.
Contribution No. 919 of the Rhode Island Agricultural Experiment Station, Kingston, R. I.

[2]Professor and Assistant Agronomist, respectively, Rhode Island Agricultural Experiment Station, Kingston, R. I.

Materials and Methods

In order to get information on what sod crops would be the most effective in maintaining or increasing potato yields, an experiment was begun at the Rhode Island Station in 1951 using six different sod crops; redtop alone, timothy alone, and mixtures of redtop-timothy, timothy-alsike clover, timothy-red clover, and redtop-alsike clover. The sod crops were grown for two years followed by two years of potatoes. There were two series of these plots so that all crops were grown every year. The plots were 1/30 acre in size with four replicates on each of the two series. Katahdin potatoes were used throughout. A ton per acre of an 8-12-12-2 fertilizer was used for the potatoes. For the sod crops a 5-10-10 fertilizer at a rate of 600 pounds per acre was used on the grass-legume mixtures and the same amount of a 10-10-10 on the grass only sods. A rye cover crop was planted following the potato harvest and plowed under either for a following crop of potatoes or for seeding the sod crops. An application of 200 pounds per acre of Cyanamid was given the rye cover crop early in the spring previous to plowing. The sod crops were clipped several times during the growing season and left on the ground.

The soil is a Bridgehampton silt loam. It was in a good state of fertility when the experiment began. This area had been used for crop rotation studies for a long period of years, but had been uniformly cropped for several years just previous to the beginning of the sod crop experiment.

Results

The yields of potatoes following two years of different sod crops for the 1953-1956 period are shown in table 1.

Table 1.—*Yields of potatoes following different sod crops in a four year rotation.*

Sod Crop	Bus. per Acre — U. S. No. 1				Average
	1953	1954	1955	1956	
Redtop	501	449	576	680	552
Redtop-timothy	488	441	544	685	540
Redtop-alsike clover	437	437	554	615	511
Timothy-alsike clover	415	426	510	619	493
Timothy-red clover	410	428	490	622	488
Timothy	364	404	517	626	478
Average	436	431	532	641	510
LSD at .05	62	NS	56	NS	32

The average yield of U. S. No. 1 potatoes varied from 478 bushels per acre following timothy sod to 552 bushels following redtop. When a combination of redtop and timothy was used the average yield was a little less than with redtop alone. A combination of redtop with alsike clover produced a slightly higher average yield than a combination of timothy with either red or alsike clover.

When the individual years of sod crop rotation are considered (Table 1) it is seen that the differences are relatively larger in 1953 and 1955

than in 1954 and 1956. One reason for this is that in 1953 and 1955 the potatoes were grown immediately following the various sod crops. In the other two years the potatoes were the second crop following the sod crops. All four years were favorable for satisfactory potato yields. The 1956 season was exceptionally favorable as shown by the higher yields. The differences in yields between treatments were not significant in either 1954 or 1956. The beneficial effect of certain sod crops was not so evident in the first year.

The specific gravity of the tubers following the different sod crops varied from year to year but there have been no consistent differences among the crops harvested following the different sod crops.

The Agricultural Chemistry Department of the Experiment Station made a study of the soil conditions following the different crops. No significant differences were found in soil organic matter, aggregation of soil particles, bulk density or moisture holding capacity. However, differences in some of these factors may become evident when the experiment has been going for a longer period of years.

The differences in yields of potatoes following the six different sod crops were not very large, in general. However, redtop or combinations of clover or timothy with redtop had a slight advantage. Redtop alone was the crop that was most easily established and required the least clipping during the season. Also, it could be left for a longer time than the two years if this became necessary. For the average potato grower in Rhode Island, redtop is probably the best all around sod crop of the six compared in this experiment for use in a rotation with potatoes. How often to grow this in a rotation with potatoes to obtain the maximum results would depend on many factors such as the soil type, original soil fertility and success in the use of cover crops. Redtop is also a dependable crop to use when the grower finds it necessary to reduce his potato acreage and plant some soil conserving crop on part of his land.

Summary

Redtop, timothy, redtop-timothy, timothy-red clover, timothy-alsike clover, and redtop-alsike clover were grown in a 4-year rotation with Katahdin potatoes. The sod crops were grown for two years followed by two years of potatoes. The sod crops were clipped and left on the ground. The average yields of potatoes for the 4-year period 1953-1956 inclusive varied from 478 bushels of U. S. No. 1 potatoes following timothy to 552 bushels following redtop. Redtop, used in combination with other crops was more effective than timothy used similarly in increasing yields of potatoes in the rotation. There were no appreciable differences in the specific gravity of the potatoes following the various sod crops. No differences were found in soil organic matter, soil aggregation, bulk density or soil moisture holding capacity following the different sod crops.

Literature Cited

1. Odland, T. E. and J. E. Sheehan. 1957. The effect of redtop and red clover on yields of following crops of potatoes. Amer. Potato Jour. 34.
2. Smith, O. 1953. Potato production in New York state. Rotations. Cornell Ext. Bull. 890. pp. 10-11.
3. Terman, G. L. 1949. Green manure crops and rotations for Maine potato soils. Maine Agr. Exp. Sta. Bull. 474.

THE EFFECT OF FERTILIZATION ON THE SUSCEPTIBILITY OF POTATOES TO LATE BLIGHT[1]

Abdul Babi Awan[2] and R. A. Struchtemeyer[3]

Although the relationship between nutrition and susceptibility to infection in various crops has been recognized by many workers (1, 2, 3, 4, 6, 9, 10, 11), only few observations (5, 7, 8) have been made regarding the effect of nutrition on late blight of potatoes. These observations have mostly been field observations and have not been verified by well planned field and greenhouse experiments.

Most of the observations have indicated that soils rich in nitrogen produced potato plants that were more susceptible to attack by disease than soils that contained large quantities of potassium and phosphorus. There was a difference of opinion as to whether phosphorus or potassium was the determining factor in the disease resistance of the plants.

Materials and Methods

The object of this experiment was to study the effect of different levels of fertilization on the incidence of late blight in potatoes. Experiments were conducted both in the field and in the greenhouse at the Maine Agricultural Experimental Station Farm at Presque Isle.

[1]Accepted for publication May 10, 1957.
[2]Former graduate student at the University of Maine, now graduate student at Pennsylvania State University.
[3]Agronomist, Maine Agricultural Experiment Station, Orono,, Maine.

The greenhouse experiment was set up in a 3 x 3 factorial design and virgin Caribou loam was used as the substrate. The rates of application on an acre basis were N: 0, 120 and 240 pounds in the form of ammonia sulphate; P_2O_5: 0, 180 and 360 pounds in the form of triple phosphate; and K_2O: 0, 180 and 360 pounds in the form of potassium chloride. Dolomitic limestone at the rate of 500 pounds per acre was added to supply Ca and Mg to all treatments. The Katahdin variety was used as the host plant.

Advantage was taken of the excellent permanent fertility plots at the Maine Agricultural Experimental Station for studies on N, P and K nutrition. The nitrogen treatments ranged from 60 to 210 pounds per acre in 30 pound increments. These treatments were replicated three times. There were 6 phosphorus treatments which ranged from 0 to 350 pounds per acre in 70 pound increments while the potassium was varied from 0 to 250 pounds per acre in 50 pound increments. The phosphorus and potassium treatments were replicated six times.

One plant was selected from each fertilizer treatment. During the regular spraying programs these plants were covered with a paper bag so that leaves used in this study did not receive a protective film of fungicidal spray.

Cultures of *Phytophthora infestans* used in this study were obtained from blight infected plants in the field and maintained in the greenhouse on potatoes of the Green Mountain variety. The spores were washed from the leaves with chilled rain water and the suspension was allowed to stand at a temperature of 62° F. for 2 hours.

From each plant representing a treatment a leaf having 5 leaflets was detached and tagged with the plot or can number of each experiment. Small balls of absorbent cotton were soaked in the spore suspension and placed on the tips of each leaflet. The inoculated leaves were placed in wooden flats having a 1 inch layer of sterilized moist peat. These flats as shown in Figure 1 were covered with glass and incubated in a chamber having a near constant temperature of 62° F. to 64° F. They were exposed to light from a fluorescent source.

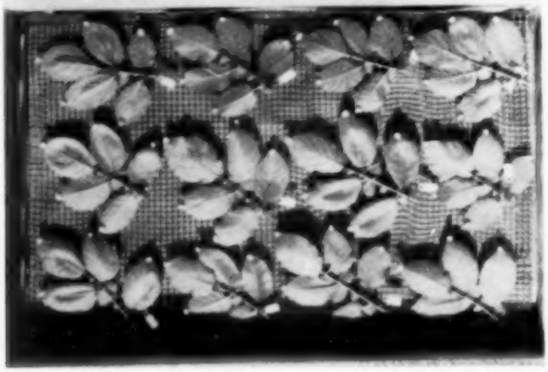


FIGURE 1.—Wooden flats showing the galvanized wire screen on which the inoculated leaves were placed.

At the end of two days the cotton balls were removed. The first sign of the disease was observed at the end of 3 or 4 days as lesions on the tips of the leaves. The blight lesions progressed down the leaves from the tips. Results were obtained by measuring the size of the lesions in millimeters.

Three sets of inoculations were performed on the leaves detached from the plants representing the N, P and K experiments in the field plot investigations. In the greenhouse experiments, following the first set of inoculation of the detached leaves, an outbreak of leaf roll prevented further separate sets of inoculation studies on this material.

Experimental Results

FIELD EXPERIMENT

Effect of N Nutrition on Late Blight:

The size of the blight lesions varied from 30 mm. to 31.6 mm. on the leaves of plants receiving 60 pounds of N per acre and from 36.7 mm. to 37.9 mm. on the leaves receiving the highest application of N, 210 pounds per acre. Significant increases in the size of the blight lesions also resulted from the use of 150 and 180 pounds of N per acre.

Effect of P Nutrition on Late Blight:

The size of the blight lesions varied from 31.2 mm. to 32.9 mm. on leaves which received no application of P fertilizer, and from 26.4 to 29.6 mm. on the leaves which received the highest application of P, 350 pounds per acre. The size of the blight lesions was smallest on the leaves which received the largest application of P per acre.

Effect of K Nutrition on Late Blight:

The size of the blight lesions varied from 32.0 mm. to 32.6 mm. on the leaves which received no application of K, and from 29.8 to 31.3 mm. on the leaves which received the highest application of K, 250 pounds per acre. The progress of the blight lesions was the most vigorous on leaves which received no application of K. As the amount of K applied increased from 0 to 250 pounds per acre the blight lesions showed a significant decrease in size.

The combined graph in figure 2 clearly shows the effect of N, P and K on the size of the blight lesions.

GREENHOUSE EXPERIMENT

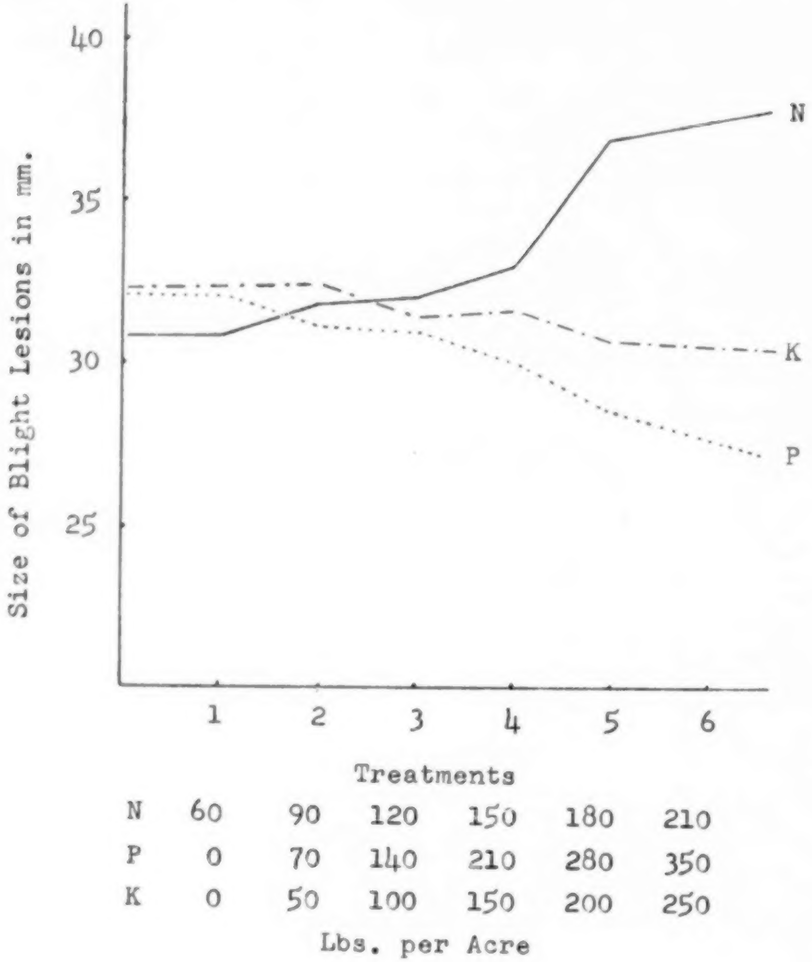
The size of the blight lesions on leaves which received no application of N was 31.1 mm. When 120 pounds of N was applied the size of the blight lesions increased to 32.1 mm., but when the amount of N was increased to 240 pounds per acre the size of the blight lesions decreased to 29.8 mm. The size of the blight lesions was 32.5 mm. when no P was applied. When the amount of P was 180 pounds per acre the size of the lesions decreased to 28.5 mm. Potassium also helped to decrease the size of the blight lesions. The size of the lesions with no application of K was 31.5 mm., with 180 pounds the size decreased to 30.8 mm., and with 360 pounds the size was 30.7 mm.

The P treatment was highly significant at the one per cent level, while the K treatment was significant at the five per cent level. The interaction between N, P and K were significant at the one per cent level.

DISCUSSION OF RESULTS

The field results of this study indicated that the increase in the amount of N applied to the soil increased the size and growth of the late blight lesions on potato leaves. This was in agreement with the results obtained by previous workers. However, excessive applications of N had no effect on the size and growth of the blight lesions on the potato leaves in the greenhouse experiment. This difference between the field and the greenhouse experiments may be due to the increased vigor and size of the potato plants grown in the field or to the outbreak of leaf roll that occurred in the greenhouse.

The results of the P and K experiments indicated that there was a marked decrease in the occurrence and progress of the late blight fungus, with each increase in the amount of P and K fertilizer applied to the soil. The results of the P and K experiments were in agreement with those obtained by Janssen (7) who concluded that the plants from low P plots were damaged most by late blight. Hoveland, Berger and Darling (6)



also reported that P deficiency caused symptoms of leaf roll to appear much earlier and with greater intensitity. This was in contrast with the work of Thomas (11) and Heigham (5) who suggested that potassium may be the determining factor in the disease resistance of plants.

Summary

Experiments were conducted in the field and the greenhouse to study the effects of N, P and K nutritions on the incidence of late blight in potatoes.

In the N experiments the results of the field and greenhouse were variable. In the field excessive amounts of N fertilizer had a marked tendency to increase the size of the late blight lesions on the potato leaves. In the greenhouse excessive use of N fertilizer did not increase the late blight lesions on the potato leaves.

The amount of P applied in the fertilizer was the most significant factor in determining the size of the late blight lesions. Large applications of P decreased the size of the late blight lesions on the potato leaves, while the progress in the size of the late blight lesions was most rapid in leaves receiving no application of P.

Significant decreases in the size of the late blight lesions resulted from the high applications of K fertilizers, but K was not as efficient as P in decreasing the size of the late blight lesions.

Literature Cited

1. Butler, E. J. 1919. Immunity and disease in plants. Abst. in Bot. Abst. 2: 176.
2. Cook, W. S. 1937. Relationship of nutrition of tomato to disposition to infectivity and virulence of *Fusarium lycopersici*. Bot. Gaz. 98: 647-669.
3. Delacroix, G. 1909. Maladies des plantes cultivees. *Maladies parasitaires*. p. 91
4. Gaumann, E. 1950. Principles of plant infection. p. 267
5. Heigham, C. 1926. The manuring of potatoes: summary of points arising at the Rothhamstead conference. Jour. Min. Agr. (Gr. Brit.) 22: 903-906.
6. Hoveland, C. S., Berger, K. C. and Darling, H. M. January 1954. The effect of mineral nutrition on the expression of potato leaf roll virus symptoms. Soil Science Society of America Proceedings Vol. 18, No. 1.
7. Janssen, J. J. 1930. Influence of fertilization on the health of the potato. Abst. in Amer. Potato. Jour. 7: 79-80.
8. Laurent, E. 1900. Experimental investigations on some diseases of plants. Abst. in Exp. Sta. Rec. 11: 550.
9. Liebig, J. 1876. Die chomie in ihrer anwendung auf agricultur und physiologie. 9th ed.
10. Miles, H. W. and Brynmor, T. 1925. A preliminary study of the relationship between manuring and susceptibility to diseases in potatoes. Jour. Agr. Sci. 15: 89-95.
11. Thomas, B. 1926. Fertilizing in relation to the disease resistance of crops. Abst. in Amer. Potato Jour. 3: 186.

CONTROL OF THE POTATO FLEA BEETLE WITH APPLICATIONS OF INSECTICIDES TO THE SOIL[1]

W. A. RAWLINS AND W. R. YOUNG[2]

Recent reports have indicated that the potato flea beetle, *Epitrix cucumeris*, is increasingly more difficult to control with DDT. This suggests resistance or tolerance, commonly the aftermath of repeated exposures over several generations of an insect species to an insecticide. Loss of the effectiveness of a material in this manner dictates a change to other insecticides of greater potency. In case of the potato flea beetle dieldrin, heptachlor, chlordane and endrin have been proven satisfactory to replace DDT in the spray and dust programs.

These insecticides are better known for control of soil insects and in this role they are promising as a means of eliminating flea beetle larvae infesting potato hills. Soil applications are an accepted practice in the potato growing areas of western United States where the potato tuber flea beetle, *E. tuberis* is a serious problem. Larvae of this species feed extensively on the tubers causing small brown flecks in the flesh. The eastern species, *cucumeris*, is largely a foliage pest, chewing small holes in the leaf tissue, but occasionally the larvae cause injury to the tubers. Recently, Hofmaster (1) obtained excellent results with soil treatment to control *E. cucumeris* attacking potatoes in the Eastern Shore of Virginia. He suggested soil application as an alternate means of controlling the flea beetle, the other method being foliage sprays or dusts.

In New York marked decreases in flea beetle infestations have resulted from soil treatments for wireworm control. This has been generally recognized by potato growers and some have been enthusiastic over soil insecticides as a means of controlling flea beetles. A soil application aimed solely at flea beetle control would be an additional operation preparatory to planting. The efficiency of such a practice is questioned since foliage applications at the proper times would also achieve adequate control. The insecticides may be added conveniently to the fungicide usually applied at frequent intervals during the growing season. However, it is conceivable that soil treatments might supercede foliage sprays or dusts in the event of beetle resistance to insecticides. This presupposes that the larvae do not acquire the same degree of tolerance as the beetles.

MATERIALS AND METHODS

1953 Test

Some research done in New York is placed on record as confirming Hofmaster's work (1) in Virginia. The potato flea beetle is not as serious in New York as in the Eastern Shore area. The investigations started in 1953 with a small plot experiment using soil applications of aldrin, dieldrin and heptachlor applied at 2 pounds per acre. The insecticides, diluted in water, were sprinkled evenly over the soil surface and tilled into the upper 3-4 inch layer.

[1] Accepted for publication May 15, 1957.
[2] Cornell University, Ithaca, N. Y.

Hill counts of larvae and pupae were taken in mid-August but the infestation was extremely uneven. Two of the replicates were heavily infested whereas the others were not. Immature stages were found only in the untreated areas indicating a favorable response and the possibility for a high degree of larval control.

An assessment of foliage injury was not made because of the preconceived notion that the beetles upon emergence would scatter with abandon and they would fail to respect the boundaries of plots. Beetles from the untreated areas might spread to plants in the treated plots giving a false impression of the effectiveness of the treatments. However, the removal and examination of the soil from the potato hills proved to be laborious, time-consuming and dependent upon a good friable condition of the soil. Rains in the midst of sampling, prolonged operations to allow the soil to dry sufficiently for handling. Examination of the soil for the small, immature forms of the flea beetle had to be abandoned.

1954 Tests

In 1954 to meet the problems posed by beetle migration single fields and large areas of fields were treated. The difficulty inherent in this layout was the lack of adequate replication and the physical restriction on the number of materials that could be compared adequately. Small plots were continued in two experiments, one in Long Island and the other in Steuben County. Most of the work was done in cooperation with commercial growers who sprayed regularly. The sprays reduced flea beetle populations considerably so that foliage injury was generally light.

The insecticides were applied to the soil after plowing and tilled into the upper layer. Beetle injury, feeding holes in the leaves, was determined after the appearance of the overwintering beetles and again after emergence of the mid-summer population.

The large scale experiments (Table 1) comprised fields on 3 farms. In one comparison heptachlor at 2.5 pounds per acre was tilled into a small field subsequently planted to Irish Cobblers for an early crop. The check was another field nearby on a neighboring farm planted at the same time and with the same variety. The third field was divided into 3 parts, one strip treated with dieldrin, one with heptachlor and the third left untreated.

TABLE 1.—*Flea beetle injuries to the foliage and tubers from treated and untreated fields.*

	Application Rate Pounds per Acre	No. Injuries on 20 Terminal Leaflets			Injured Tubers
		6/8	6/29	7/27	Per cent
Field 1 Heptachlor	2.5	388	502	253	8
Field 2 Untreated	None	1245	890	3307	57
Field 3 Dieldrin	1.8	.....	53	18	0
Heptachlor	2	.....	43		1
Untreated	None	.....	458	39	25

Results

Counts of injuries on 20 terminal leaflets taken during June prior to the appearance of the mid-summer brood of beetles indicated that the soil treatments had reduced the feeding of the overwintering population. Presumably the beetles may have been killed by contact with the treated soil during egg laying activities. Later in the season data were obtained on the feeding of the summer population during late July. Marked reductions in injury were noted in the treated areas. Plants in field 3 were sprayed with DDT at the time of beetle emergence. Obviously, the beetles in this field were not DDT tolerant. The other two fields were not sprayed with an insecticide. Reduction of the overwintering populations markedly decreased larval feeding on the tubers.

Assessment of beetle injury in the small plots, each 1/100 acre in area, was a pleasant surprise. The data are summarized in table 2 for the Long Island experiment. In spite of the light infestation very significant differences were noted between the untreated checks and the treatments. All the treatments performed similarly. The reduction of foliage injury by the preplanting soil treatment was more than 90 per cent which is as good or better than foliage insecticide applications.

Table 2.—*Mean number of flea beetle feeding injuries on 60 terminal leaflets collected from plants grown in treated soil. Long Island. July, 1954.*

Treatment	Application Rate	Number of Injuries	Per cent Reduction
	Pounds per Acre		
Untreated		452.1	
Isodrin	1	36.2	92.0
Lindane	2	34.2	92.4
Dieldrin	2	23.8	94.7
Heptachlor	2	23.2	94.9
Aldrin	2	22.5	95.0
LSD 5 per cent		191.4	

The second small plot experiment in Steuben County was lightly infested due largely to a DDT spray applied at the time of beetle emergence. The differences in injury among treatments (Table 3) were more widely spread than in the previous experiment. Despite these differences the only significant comparison is between the untreated and the treated as a group. The inter-replicate variation within treatments was rather large, a result not too unexpected with a light infestation.

The Long Island plots were replanted in 1955 without further treatment. Injury in treated areas was sparse again. In the untreated plots counts were of the same order as the previous year. However, no differences in magnitude of injury was evident among the checks and treatments indicating a loss of effectiveness of the insecticides after one season.

The results of these investigations confirmed the work of Hofmaster

TABLE 3.—*Mean number of flea beetle injuries on 60 terminal leaflets collected from plants grown in treated soil. Steuben County. August, 1954.*

Treatment	Application Rate	Number of Injuries	Per cent Reduction
Untreated	Pounds per Acre	425.0	
Aldrin (e.c.)	3	229.5	46.0
Endrin	1	176.5	58.5
Lindane	1	155.0	63.5
Aldrin (gran)	3	139.2	67.3
Chlordane (gran)	6	127.8	69.9
Isodrin	1	100.8	76.3
Chlordane (e.c.)	6	83.8	80.3
Heptachlor	2	80.8	81.0
Dieldrin	2	75.5	82.2
Endrin		62.5	85.3
L.S.D. 5 per cent		130.9	

(e.c.)—Emulsifiable concentrate
(gran)—Granular formulation

(1). Insecticides introduced into the soil were effective in reducing damage from the feeding of the potato flea beetle. Control is due to a reduction of the larval population in the soil.

LITERATURE CITED

1. Hofmaster R. N. 1957. Potato flea beetle control by the application of insecticides to the soil. The Vegetable Growers News 11, 8: 1-4.

LARGEST POTATO WANTED

The National Potato Chip Institute is searching for "SPUDNIK"—the world's largest potato.

A $100 U. S. Savings Bond will be presented to the person who submits the biggest spud, in what is believed to be the first such contest.

The contest is open to anyone who believes he or she has an exceptionally large potato and all entries should be sent to the National Potato Chip Institute, 946 Hanna Building, Cleveland, Ohio.

All entries will become the property of the National Potato Chip Institute and will not be returned.

The world's largest potato will be displayed along with the world's largest potato chip—supplied by a chip manufacturer—at the 21st Annual NPCI Conference at the Hollywood Beach Hotel, Hollywood, Florida, January 22-26, 1958.

EFFECT OF ILLUMINATION AND WAXING ON THE CHLOROPHYLL DEVELOPMENT IN SCRUBBED WHITE ROSE POTATO TUBERS[1]

F. D. Howard[2], M. Yamaguchi[2] and H. Timm[3]

White Rose potato tubers harvested in the fall and winter in California have been observed to green excessively while displayed in the retail markets. It has been suggested that the greening might be due to washing and scrubbing practices employed at the packing sheds. Potatoes grown in the early spring are harvested relatively immature with a thin pale skin. At full maturity, however, the skin is thicker and darker brown. The tubers can be quite dirty when dug after the winter rains commence. Since buyers demand that they be as light in color and smooth-skinned as possible, newly harvested potatoes are scrubbed in water through a series of 24, 48, or 72 brushes in order to remove soil and some of the outer tissue.

Experiments were conducted to determine the relationship of scrubbing to subsequent greening and what steps might be taken to reduce it. The effects on the chlorophyll development in potatoes from scrubbing with different numbers of brushes, waxing, and covering with burlap were included in these studies.

Materials and Methods

A preliminary survey showed that potatoes displayed in local supermarkets received from 35 to 150 foot-candles from fluorescent ceiling lights. Usually it was about 70 foot-candles. Sometimes an incandescent spotlight in the ceiling was focused on the potatoes. A daily exposure of 10 to 12 hours is normal in stores.

Since Isenberg (1) found little differences between continuous and intermittent illumination in his studies of chlorophyll development in potatoes, continuous light was used in all these experiments. The potatoes were placed on tables under banks of fluorescent lights (cool white) and received approximately 65 to 70 foot-candles. White Rose potatoes of fairly uniform size, obtained from packing sheds, were transported to Davis in cardboard cartons covered with a tarpaulin. The tubers in the check lots were hand-washed in the laboratory to remove soil.

Experiment 1. Potatoes grown near Riverside, California, planted March 14, 1956, were harvested on July 25, two weeks after the tops went down due to withholding of water. Tubers were selected before and after being washed through a series of 24 or 48 brushes. The skins were quite thin and were partly removed by brushing.

The treatments were set up as a randomized split plot design, brushes being the main treatment and burlap coverings (7½ and 10 oz.) the

[1]Accepted for publication May 15, 1957.
Supported in part by a grant from the Long White Potato Advisory Board.
[2]Assistant Olericulturists.
[3]Junior Olericulturist, Department of Vegetable Crops, University of California, Davis, Cal.
[4]The authors wish to make acknowledgments to Prof. J. E. Knott who initiated this study and has given many helpful suggestions during the investigation and in the preparation of the manuscript. Also to Mr. D. Rubenstein for the assistance in the chemical analyses.

sub-treatment, with four replications of 25 tubers each. The light intensities under the 7½-oz. and 10-oz. burlap ranged from 15 to 20 and 4 to 8 foot-candles, respectively (as measured by a Weston Light Meter). For the dark treatment, the tubers were kept in potato cartons. The potatoes were exposed to the light for 93 hours at a room temperature of approximately 80° F. This would be equivalent to about eight days of market display. The exposed surface of the upper half of the tubers was used in the chlorophyll determination. The tissue containing chlorophyll was removed with a potato peeler and chopped. Fresh samples weighing 100 grams were put into plastic bags and quick-frozen with dry ice.

Experiment 2. Potatoes grown near Shafter, California, were planted July 25, 1956, and harvested December 13. The tops gradually went down about one month before harvest. The tubers, scrubbed through a series of 48 brushes, were compared with unscrubbed ones.

Johnson's Clearfresh Wax No. 5716 was applied to the scrubbed tubers. A small cellulose sponge saturated with the liquid wax was squeezed so that the sponge was slightly damp to the touch. The wax was then applied to the tubers, leaving a thin film on the surface. The waxed tubers were air-dried for 15 minutes before being exposed to the lights.

The treatments—check, 48 brushes, and 48 brush-waxed—were set up in a randomized block design with four replications of 50 tubers each. The tubers were illuminated at about 70 foot-candles for 70 hours at a room temperature of approximately 75° F. This would be equivalent to nearly six days of market display.

Twelve cores approximately one square centimeter in area were removed from the exposed surface of the tubers with a cork borer. Discs approximately one millimeter thick, which contained all the chlorophyll tissue, were cut from these cores. All discs from a single replication were mixed in a beaker of water and 100-disc samples were frozen for each determination.

Experiment 3. The potatoes planted near Hemet, California, during August 1 to 3 were used in this test. The tops were killed by frost on November 3. The tubers were harvested on January 31, 1957, and washed and scrubbed with 48 or 72 brushes. Unscrubbed tubers served as checks.

The treatments were set up in a split plot design as in the first experiment, with brushes as the main treatment and burlap coverings as the sub-treatment. The treatments were replicated three times with 30 tubers in each replication. Samples from all treatments were taken after 24- and 43-hour exposures to light except that no sample was taken from the 72-brush treatment after 24 hours of illumination. The rest of the potatoes continued to be illuminated for a total of 67 hours under light conditions similar to experiment 1. This period would be equivalent to approximately six days of market display.

The tubers were sampled as in experiment 2 except that the discs from the apical and stem end were analyzed separately. After quick-freezing, the discs were lyophilized and then ground in a Wiley Mill. The data on apical and stem-end chlorophyll content were subjected to the t-test.

Chlorophyll Analysis

Chlorophyll was determined by the alcohol extraction method

described by Larson (2). The standard curve for chlorophyll was obtained from a modified procedure of the A.O.A.C. (3) as communicated by Isenberg (1).

The results in experiment 1 are given as mg/100 g fresh weight of potato peel and in experiments 2 and 3 as mg/100 sq. cm. of surface.

RESULTS

Experiment 1. The results of this experiment, as shown in table 1, show that brushes did not influence the greening in the uncovered tubers or in those covered with 7½-oz. burlap. Under 10-oz. burlap there was no difference between treatments except for the 48-brush treatment which contained significantly more chlorophyll than the unbrushed. Covering with burlap significantly decreased the chlorophyll content of the tubers compared with those fully exposed. The heavier burlap effected a greater decrease in the chlorophyll content.

Experiment 2. After 21 hours of illumination the checks appeared slightly green, and the 48-brush and 48-brush-waxed treatments showed definite greening. After 46 hours the checks showed definite greening (grayish-green), whereas the other treatments appeared much greener than after 21 hours of illumination. The 48-brush and 48-brush-waxed treatments appeared similar in color, but the checks were definitely grayish and lighter green after 70 hours. This was probably due to the effect of skin thickness which masked the green color.

The chlorophyll contents are shown in table 2. There was no significant difference between treatments. Neither waxing nor brushing had any effect upon greening.

Experiment 3. After 24 hours of full light, a very slight green tint was observed in all treatments. At 43 hours all treatments showed definite greening; the checks appeared brownish-green. No color differences were visible between the 48- and 72-brush treatments. At the end of the experiment (67 hours) all tubers appeared green. The checks still remained brownish-green as noted after 43 hours. The potatoes under burlap were not so green as those exposed to light.

Table 3 shows the chlorophyll content of the different treatments. There was no significant difference caused by brushes after 24 or 43 hours in full light; with brushing, however, there was a trend for higher chlorophyll content. After 67 hours of illumination the 48- and 72-brush treatments showed significantly higher chlorophyll content than the no-brush treatment. The apical ends of tubers from the 72-brush treatment were significantly higher in chlorophyll than those of the 48-brush treatment exposed for 67 hours. As was found in Experiment 1, covering with burlap significantly decreased the chlorophyll content — the heavier the burlap, the lower the chlorophyll content. The chlorophyll content of the tubers in full light increased with length of exposure. The chlorophyll content of the apical end was significantly higher (1 per cent level) than that of the stem end.

TABLE 1.—*Effect of scrubbing and covering with burlap on chlorophyll content of White Rose tubers illuminated with 65 to 70 foot-candles for 93 hours. Average of 4 replications.*

Number of Brushes	Light	7½-oz. Burlap	10-oz. Burlap	Dark	LSD 1 Per cent	LSD 5 Per cent
	(Mg. Chlorophyll per 100 Gms. Peels F.W.)					
0 (Check)	0.53	0.34	0.22	0.01	0.04	0.06
24	0.54	0.38	0.27	0.01	0.04	0.06
48	0.57	0.36	0.29	0.01	0.04	0.06
LSD 5 per cent	0.06	0.06	0.06			
LSD 1 per cent	0.09	0.09	0.09			

TABLE 2.—*Effect of waxing on the chlorophyll content of scrubbed White Rose potatoes illuminated with 70 foot-candles for 70 hours. Average of 4 replications.*

Treatment	Light	Dark
	(Mg. Chlorophyll per 100 Sq. Cm.	
0 (Check)	0.22	0.01
48 brushes	0.24	0.01
48 brushes-waxed	0.23	0.01
LSD 5 Per cent	0.03	

DISCUSSION

In Experiment 1 no difference was detected between any treatment except for the 48-brush treatment covered with 10-oz. burlap which contained more chlorophyll than the unbrushed. This may have been due to the long period of illumination (93 hours) or to the poor skin development, as the tubers were harvested only two weeks after the tops were down. Many tubers showed "feathering" as compared with those used in the other experiments.

Waxing apparently did not reduce the light intensity enough to cause any differences in chlorophyll development.

No differences were noted between the unbrushed and the brushed treatments in Experiment 2. In this case the skin of the unbrushed tubers was relatively thin and apparently had little effect on the amount of light transmitted to the live cells below. However, the brushed tubers showed a trend toward a higher chlorophyll content.

The tubers of Experiment 3 were in the ground for nearly two months after the tops had died down. Their skin was well developed, being quite thick and brown. In this case scrubbing with 48 or 72 brushes cleansed the potatoes enough so that they appeared definitely lighter in color. Tubers of the previous experiments (1 and 2) did not have this brownish russeting

TABLE 3.—*Effect of scrubbing, intensity of light, and length of exposure on the chlorophyll content of apical and stem ends of White Rose potatoes. Average of 3 replications.*

Number of Brushes	Dark[1]		24 Hours		43 Hours		67 Hours					
			65-70 F.C.		65-70 F.C.		65-70 F.C.		15-20 F.C.[2]		4-8 F.C.[3]	
	Apex	Stem	Apex	Stem	Apex	Stem	Apex	Stem	Apex	Stem	Apex	Stem
	(Mg. Chlorophyll per 100 Sq. Cm.)											
0 (Check)	0.006	0.003	0.057	0.047	0.123	0.105	0.250	0.208	0.153	0.144	0.132	0.112
48	0.005	0.003	0.062	0.057	0.139	0.118	0.277	0.247	0.213	0.198	0.177	0.154
72	0.005	0.003	....	....	0.142	0.127	0.306	0.257	0.205	0.192	0.176	0.157
LSD 5 Per cent	N.S.	N.S.	N.S.	N.S.	N.S.	0.020	0.015	0.005	0.015	0.005	0.015	0.005
LSD 1 Per cent	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.025	0.007	0.025	0.007	0.025	0.007
LSD for full light, 7½-oz. and 10-oz. burlap for 67 hour exposure												
5 per cent									0.025	0.016		
1 per cent									0.035	0.022		

[1]Potatoes kept in covered potato carton
[2]Potatoes covered with 7½-oz. burlap
[3]Potatoes covered with 10-oz. burlap

appearance. After 67 hours of exposure under full light, scrubbed tubers showed an increase in chlorophyll content. The heavier the burlap used to cover the potatoes, the greater was the reduction in chlorophyll development. There was no difference in the chlorophyll development between the 48- and 72-brush treatments under either weight of burlap.

Chlorophyll formation in the tuber appears to be a function of light intensity as well as length of exposure.

The apical end of the tuber appeared greener than the stem end, and this was verified statistically.

If the trade demands that potatoes be scrubbed at the packing shed, precautions should be taken to reduce chlorophyll development in the retail store. This can be done by keeping potatoes in the dark in cartons and only displaying enough from day to day to satisfy consumer demand. The use of consumer-size bags made of 10-oz. burlap would reduce greening. Since the tubers next to the burlap in any bag will gradually become green, the bags should be kept in the dark and displayed under lights only in such numbers as needed each day

Summary

White Rose potato tubers, scrubbed through a series of 24, 48, or 72 brushes, were exposed to fluorescent light for various periods of time. Scrubbed tubers contained more chlorophyll. Tubers under burlap were less green than those exposed to full light. Those under 10-oz. burlap showed less greening than those under 7½-oz. burlap. Waxing the tubers had no effect on chlorophyll formation.

Ways to reduce chlorophyll development in potatoes are suggested.

Literature Cited

1. Isenberg, F. M. 1956. Private communication.
2. Larsen, E. C. 1949. Investigations on cause and prevention of greening of potato tubers. Univ. of Idaho Res. Bull. No. 16.
3. Official Methods of Analysis of the Association of Official Agricultural Chemists. 1950. 7th ed. P. 112.

USDA PROPOSES REVISION OF GRADE STANDARDS FOR POTATOES

Changes in U. S. Standards for potatoes were proposed recently by the U. S. Department of Agriculture.

During the past 25 years, since the last significant change was made in these U. S. Standards, the quality of potatoes and handling methods for them have improved appreciably and consumers now expect better appearance and quality, USDA marketing officials explained.

The potato industry was surveyed last spring to measure the adequacy of existing U. S. grades. A majority of the 900 replies from individual and industry groups, representing all sections of the country and all segments of the industry, indicated that the respondents customarily packed, sold, or bought potatoes of a higher quality than the U. S. No. 1 grade, which is the primary trading grade used in merchandising potatoes.

Therefore, officials said, the Department is proposing that "the standards for potatoes be revised to bring them into alignment with current marketing practices and to make them a better, more realistic trading device."

At the present time there are five wholesale grades for potatoes, U. S. Fancy, U. S. Extra No. 1, U. S. No. 1, U. S. Commercial, and U. S. No. 2, in addition to two consumer grades, U. S. Grade A and U. S. Grade B, which are further subdivided into four size requirements.

Under the proposed revision, the U. S. Fancy grade would be eliminated. It is not now extensively used. It is proposed that requirements for the U. S. Extra No. 1 be tightened in respect to maturity, cleanliness, and tolerance for defects, so that this grade will provide a practical basis for wholesale buying and selling premium pack potatoes. The revised U. S. Extra No. 1 grade would also be suitable for use by packers who wish to buy potatoes for packing U. S. Grade A in consumer-size packages, without incurring excessive wastage or shrinkage.

Tolerance for defects would be reduced in three grades. The limit for defects in the U. S. Extra No. 1 grade would be 5 per cent. For U. S. No. 1 and U. S. No. 2 grades, an 8 per cent total tolerance for defects is proposed, including not more than 5 per cent of either external or internal defects. The tolerance for defects in the U. S. Commercial grade would remain at 20 per cent with the same tolerance for culls as is established in the U. S. No. 2 grade.

The 3 per cent tolerance for potatoes affected by bacterial wilt, ring rot, or late blight would be retained in all grades except in U S. Extra No. 1 where it would be reduced to 2 per cent. The tolerance in all grades for potatoes affected by freezing injury, soft rot, or wet breakdown would be reduced to one-half of 1 per cent at shipping point, but would remain at 1 per cent for inspections performed en route or at destination.

Present standards for potatoes provide minimum size requirements for each grade. It is proposed that the revised standards be brought into conformity with those for a number of other fruits and vegetables by dropping specific minimum size requirements and basing grade determinations on other quality factors only. Specialized size, weight, or count

classifications have been adopted so generally by the potato industry that an arbitrary minimum size in the grade is no longer useful or practicable, officials said. Improved Size A and Size B classifications, and a new Size C classification, are proposed for optional use along with the standards for potato grades.

The proposed revised standards provide that a minimum size or weight, or a count per container, may be specified for a lot of potatoes in connection with a U. S. grade.

A number of changes of lesser importance are contained in the proposed standards which were published in the Federal Register of November 8, 1957. A period of 90 days following publication, or until February 7, 1958, is provided for interested persons to submit views or comments to the Fruit and Vegetable Division, Agricultural Marketing Service, USDA, Washington 25 ,D. C.

If it appears to be desirable, officials said, the Department will schedule additional national or district meetings to discuss the matter with industry groups.

It is the Department's intention to make July 1, 1958, the effective date of any revised standards which may be adopted, based on the proposed revision issued today.